Thunderstorm Generation of Cirrus From an ER-2 Radar Perspective

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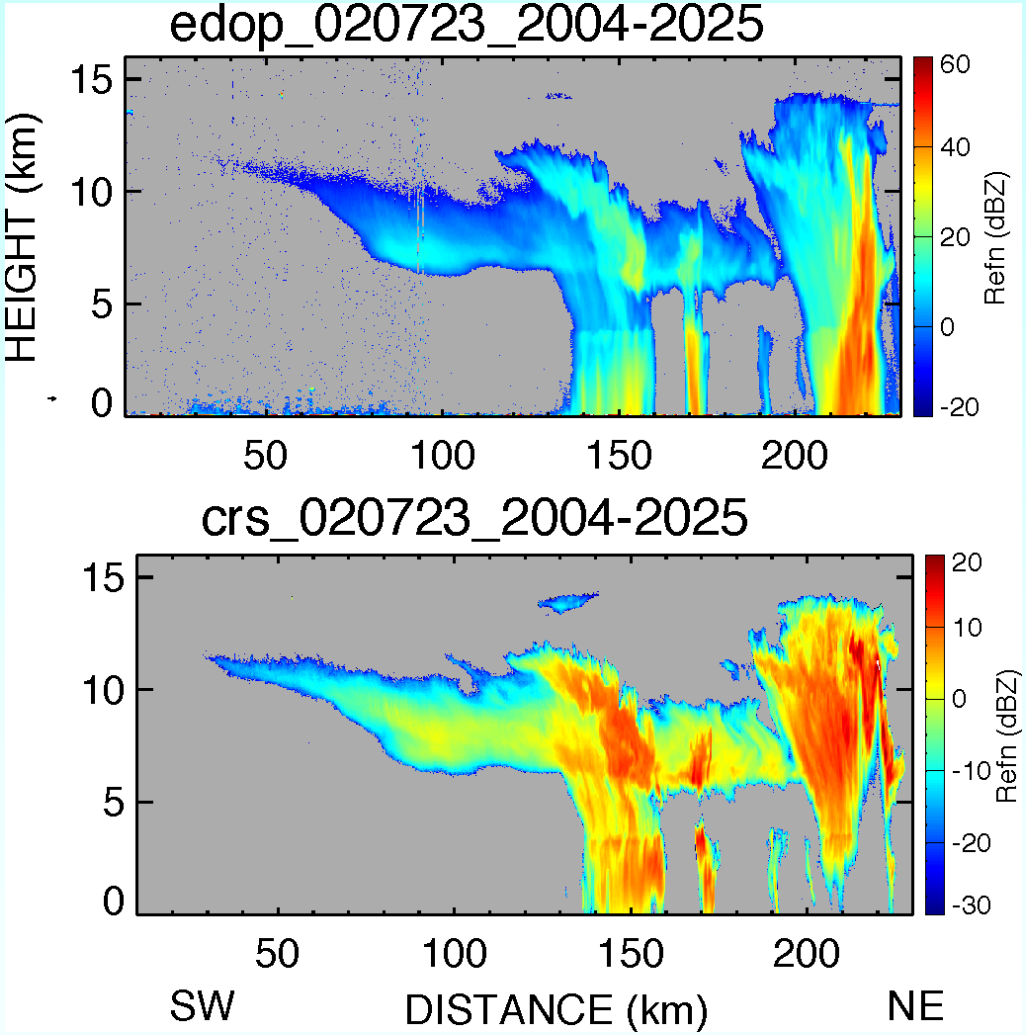
Collaborations
Starr et al., McGill, Mace, Z. Wang,
J. Wang, A. Heymsfield, F. Evans,..

Objectives

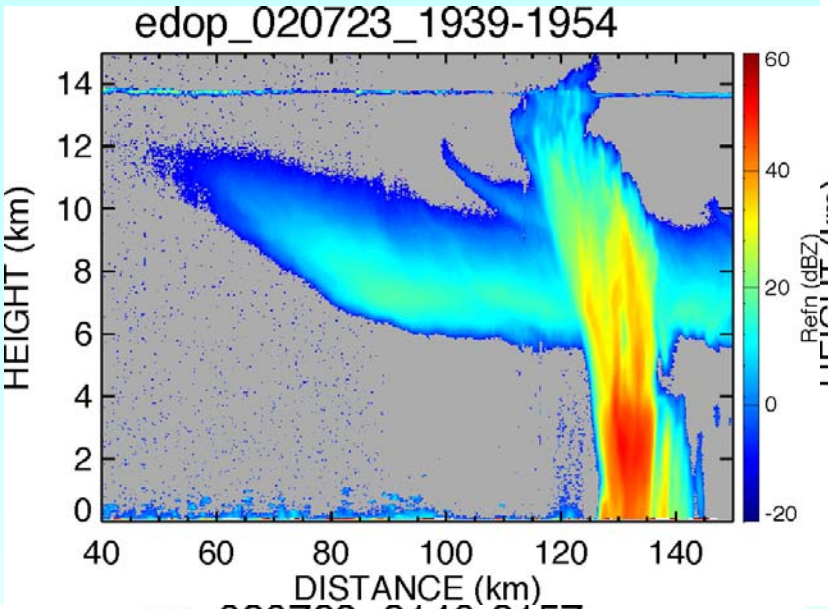
- Document vertical and horizontal wind structure at upper levels of thunderstorm generated anvil cirrus using EDOP and CRS.
- Examine the role of wind shear on thunderstorm cirrus generation.
- Relate the EDOP and CRS-based IWC, fallspeeds, particle size, etc. to the overall structure of the thunderstorm-generated cirrus.
- Cases: 23 July, 28 July, 29 July, 7 July, 19 July, 9 July

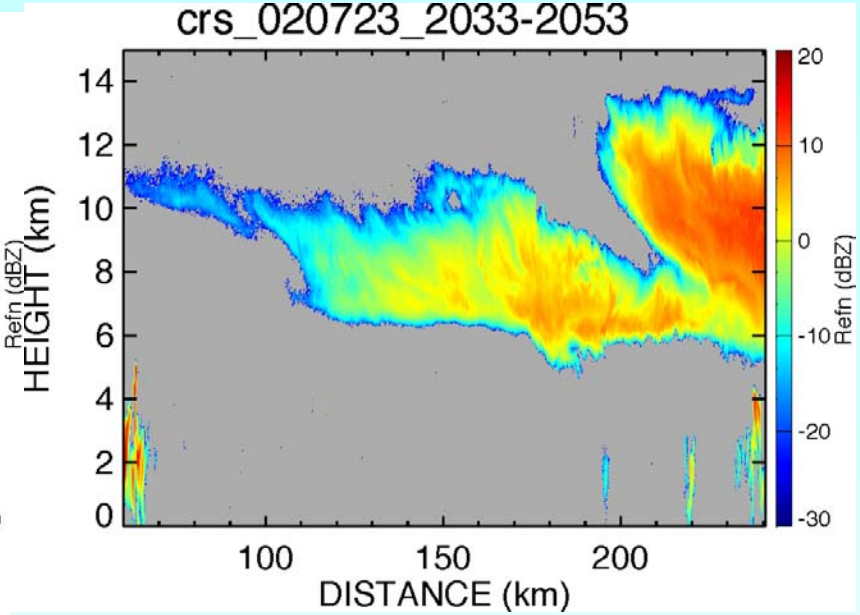
EDOP and CRS Reflectivity

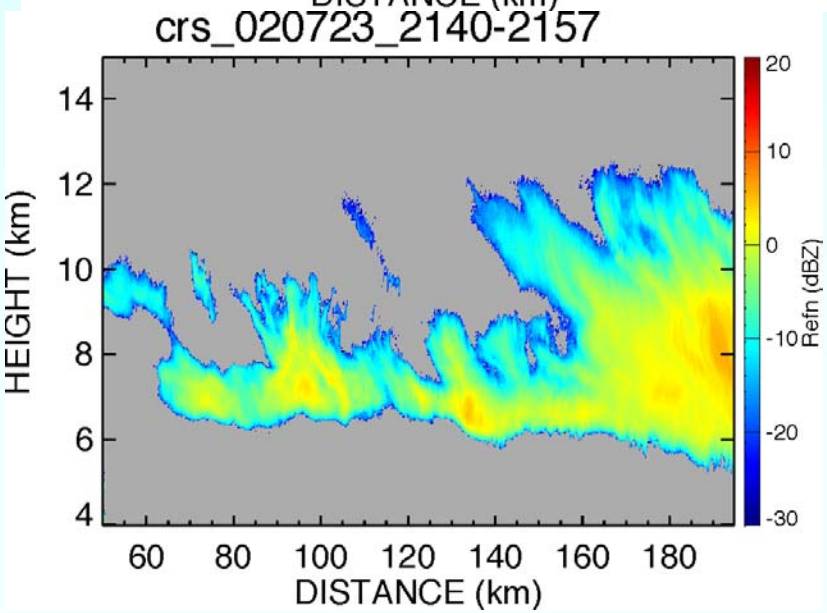


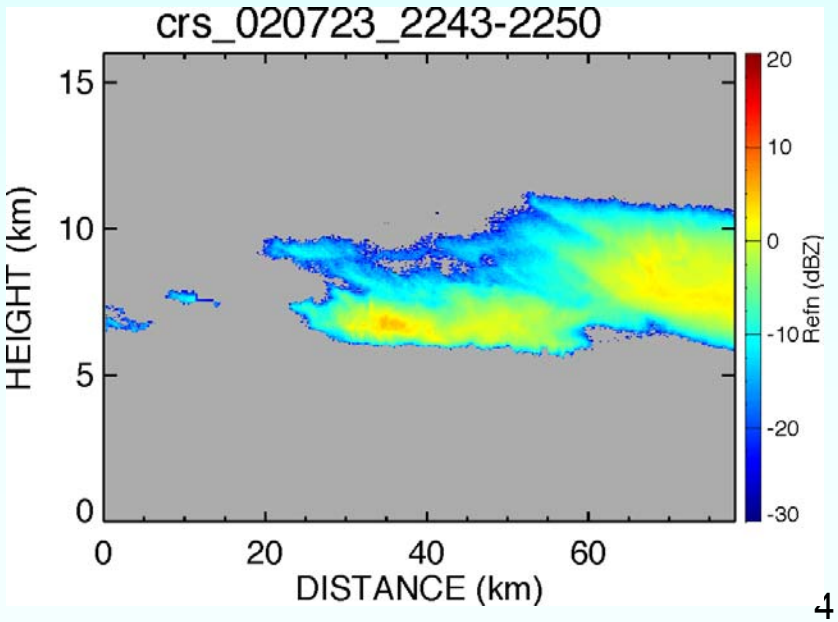
Time Sequence of Passes on 23 July

Southwest to Northeast



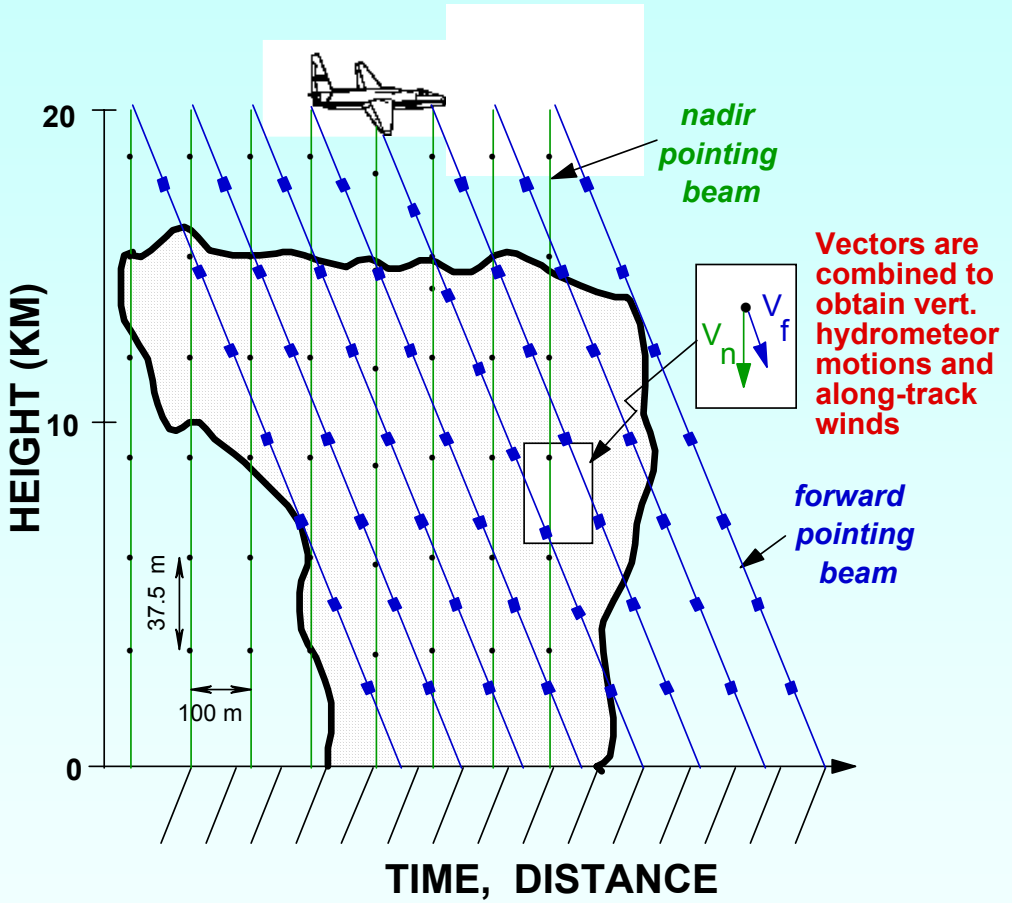






ER-2 Doppler Radar (EDOP)

- Precipitation radar located in nose of NASA ER-2 high-altitude aircraft emulates satellite view
- Coherent Doppler operation at X-band (9.6 GHz) frequency
- Dual-fixed antennas for nadir and forward views along aircraft track
- Forward beam provides dual polarization capability for microphysical characterization of precipitation (liquid, snow, hail)



- *Gate Spacing (vertical res.)* 37.5 m
- *Max. Unambiguous Range* 35 km — *Nyquist Velocity* 34 ms^{-1}
- *Along-track sampling* 100 m — *Footprint at surface (nadir)* 1.1 km
- *4 Receivers: Nadir, Nadir Surface, Forward Co-Pol, Forward Cross-Pol*

Minimum detectable signal ~ -20 dBZ_e at 4.4 kHz PRF, 0.5 s average, 10 km range.

EDOP and CRS Vertical Air Motions

$$v_d = v_f - w_a - V_{ac}$$

v_d = measured Doppler velocity

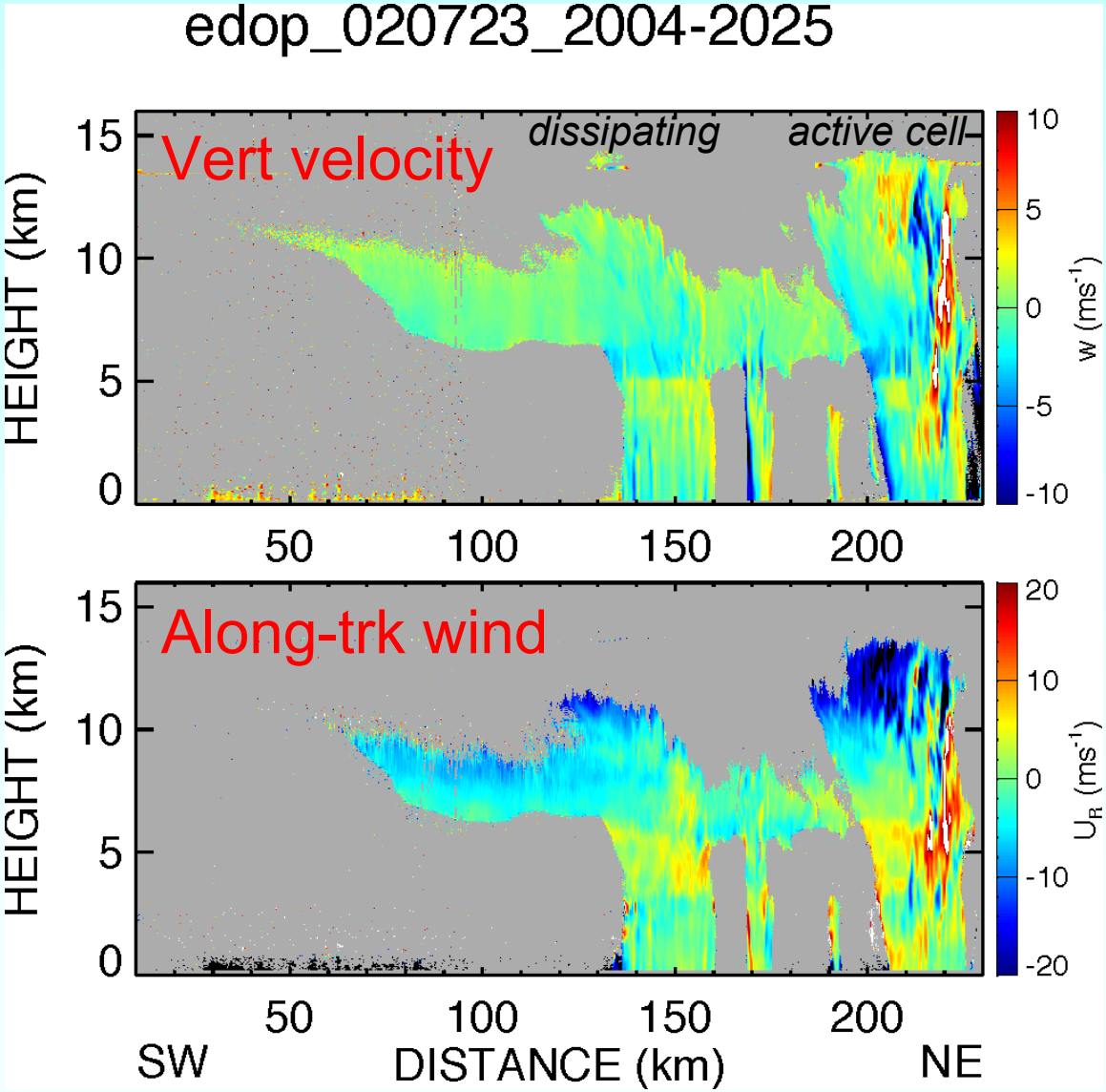
V_{ac} = aircraft motion

v_f = hydrometeor fallspeed

w_a = air vertical motion

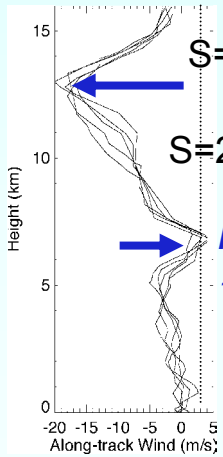
- Doppler velocities very accurate (0.1 ms^{-1}) except near cloud edges and very high-shear regions.
- Aircraft motion correction from very good (few tenths ms^{-1}) to much worse (1.0 ms^{-1}) in ER-2 - level gravity wave regions.
- Vertical velocity estimate depends on fallspeed estimate accuracy.

EDOP-Derived Winds



Mobile Soundings

Along-track wind



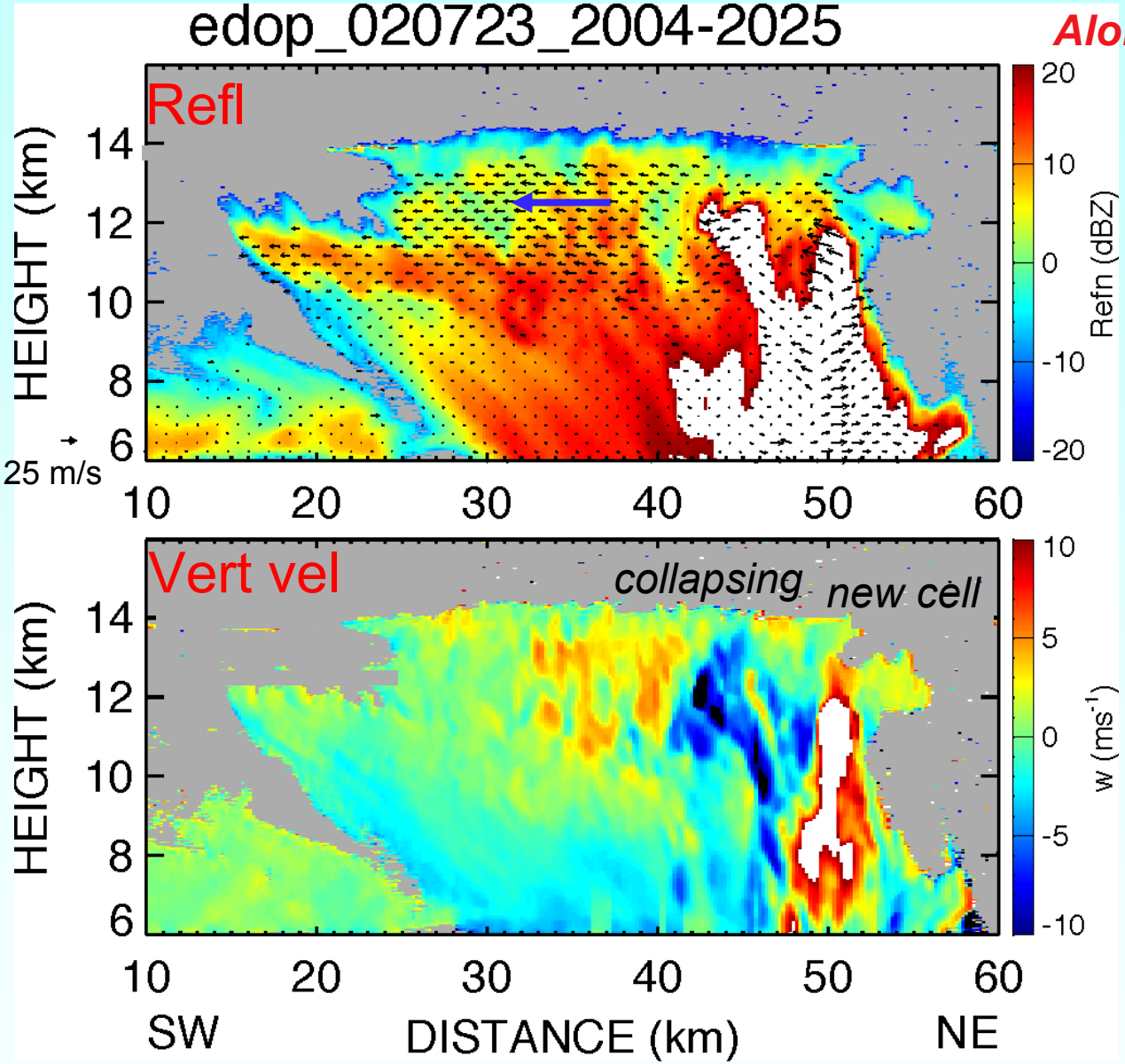
$S=6.5\times10^{-3}s^{-1}$

$S=2\times10^{-3}s^{-1}$

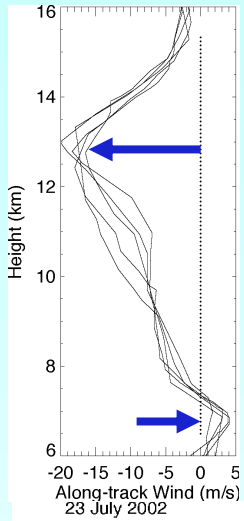
Peak wind

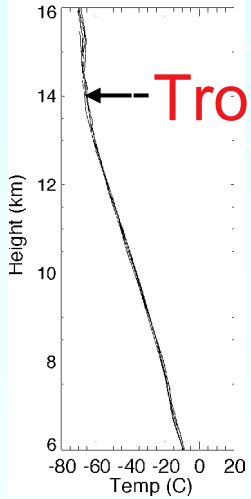
18 ms^{-1} @13 km

Cells in Different Stages of Development

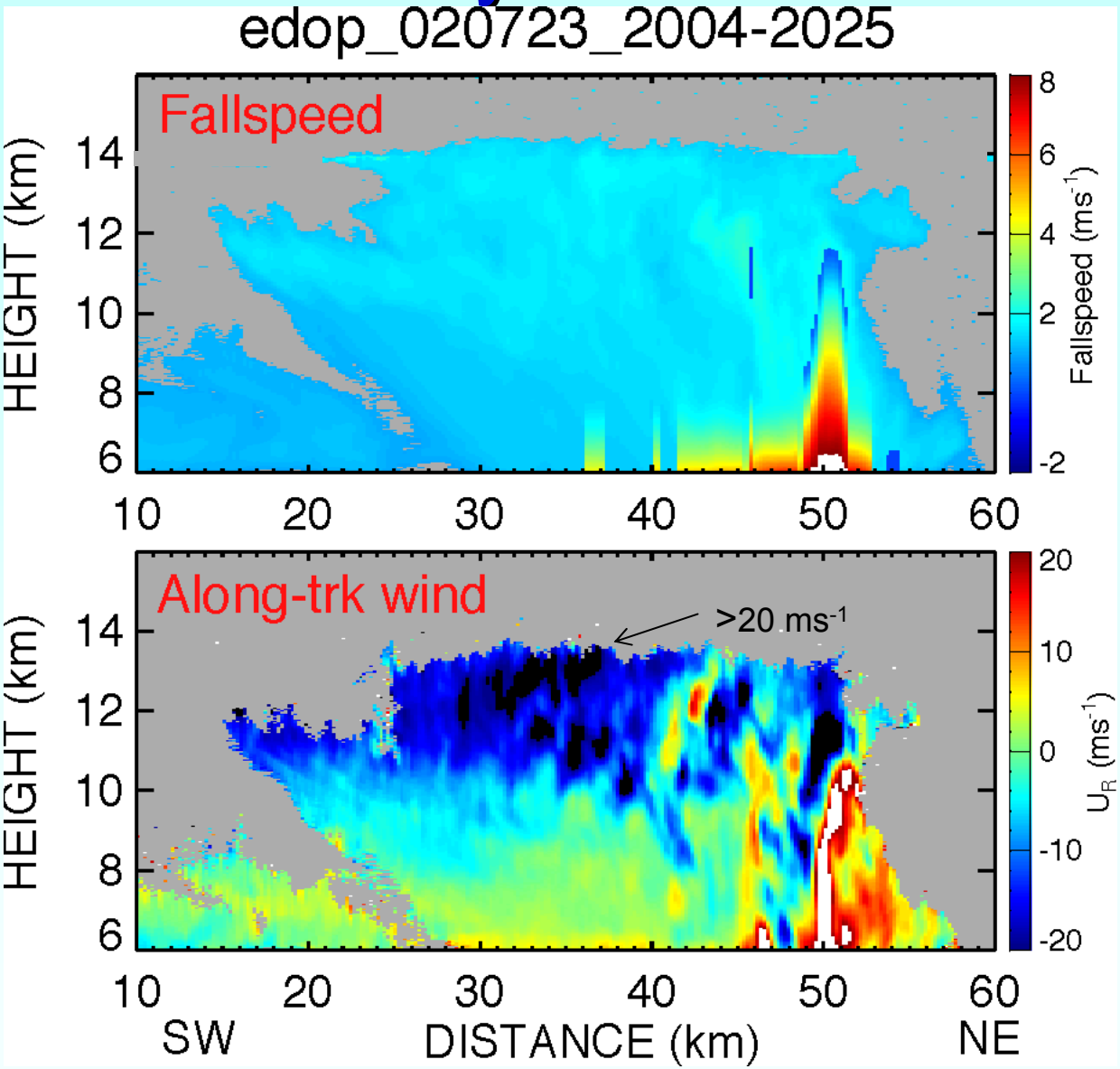


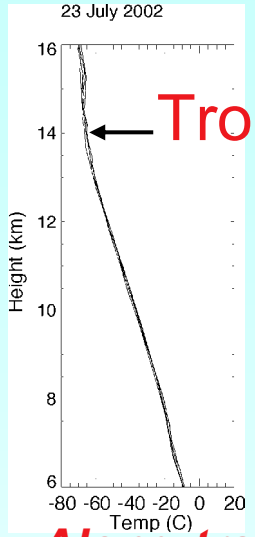
Along-track wind



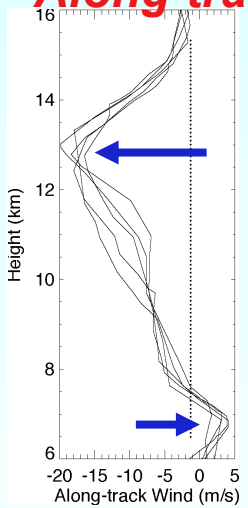


EDOP 23 July 2003 2004-2025 UTC

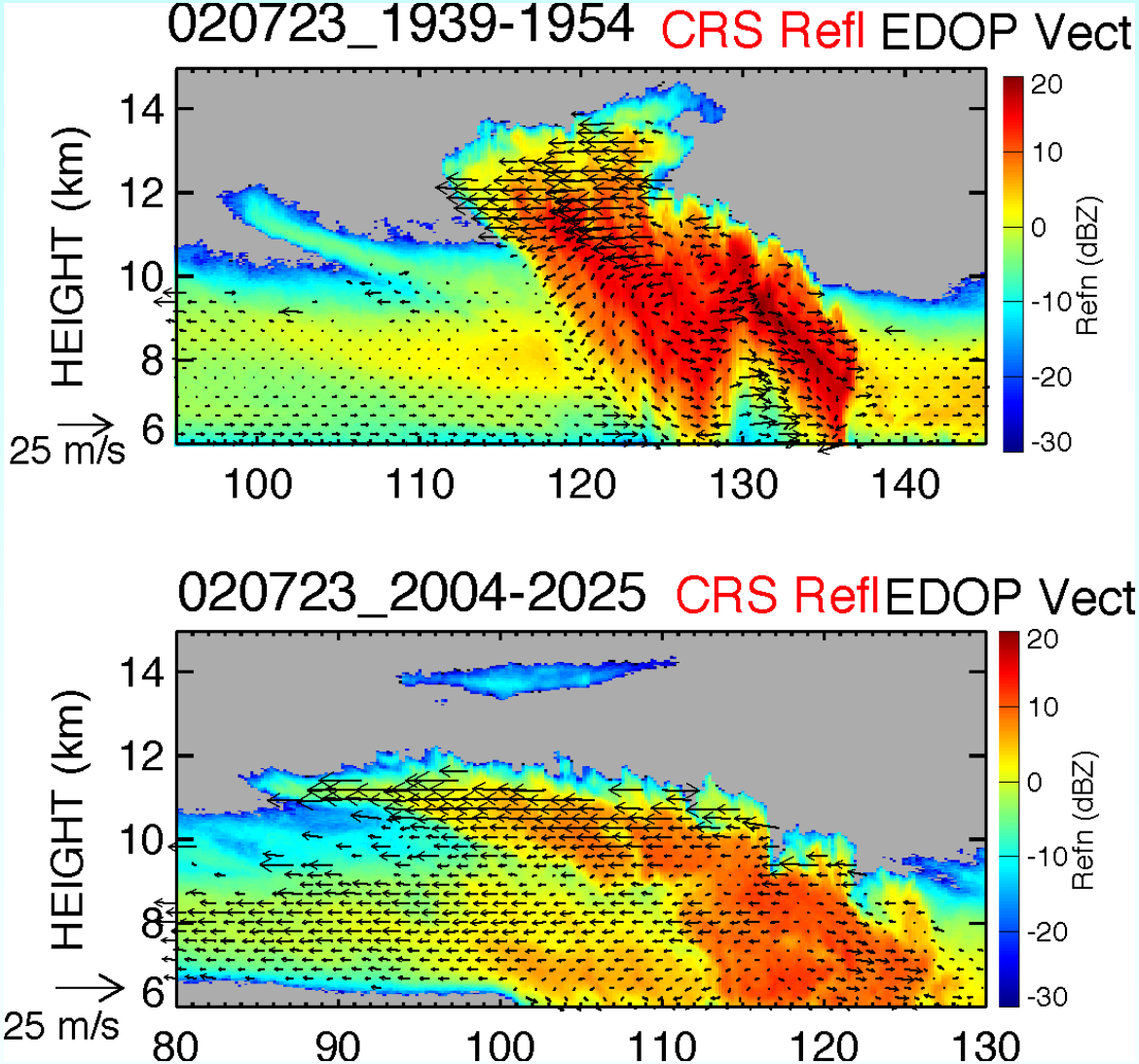




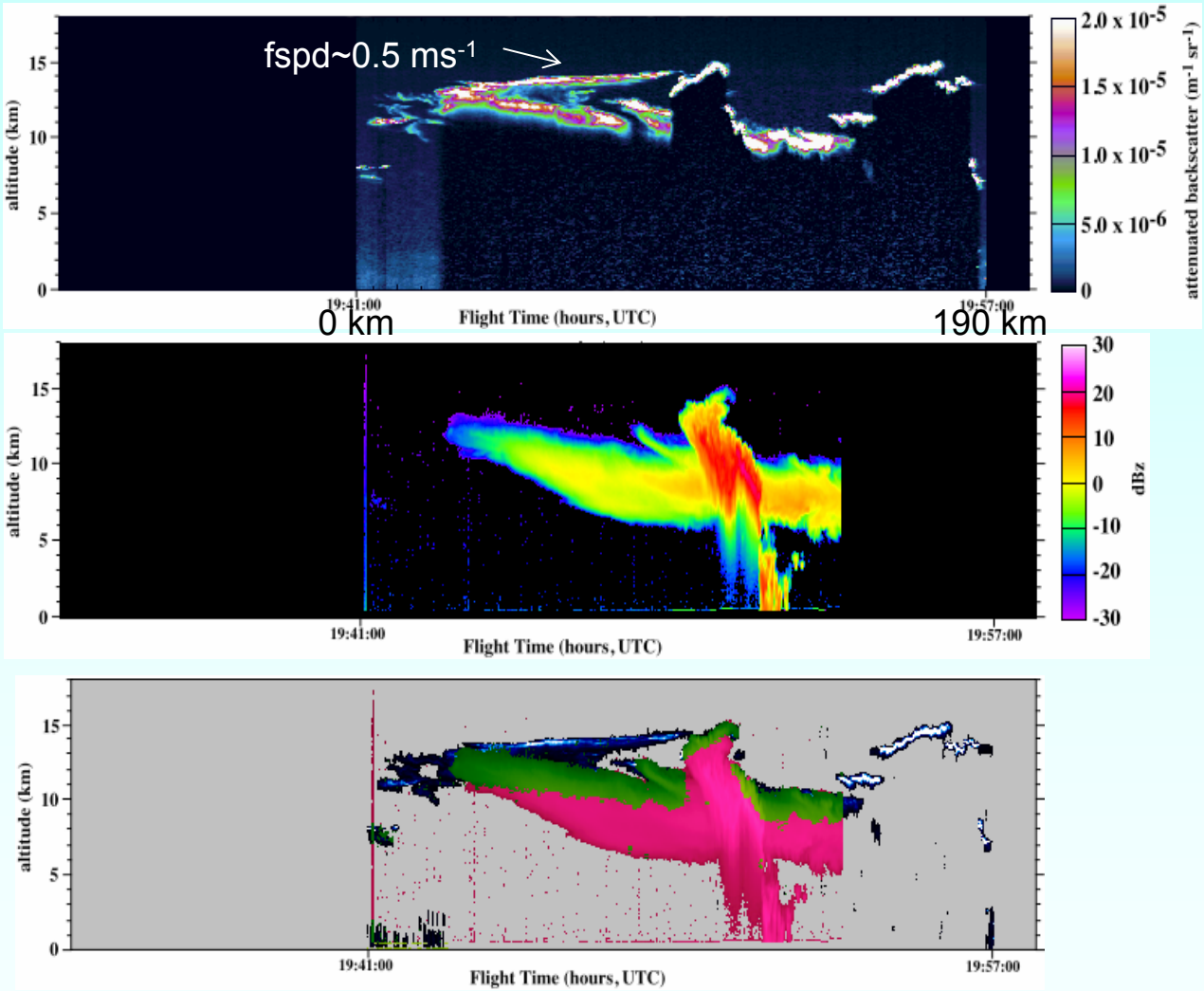
Along-track wind



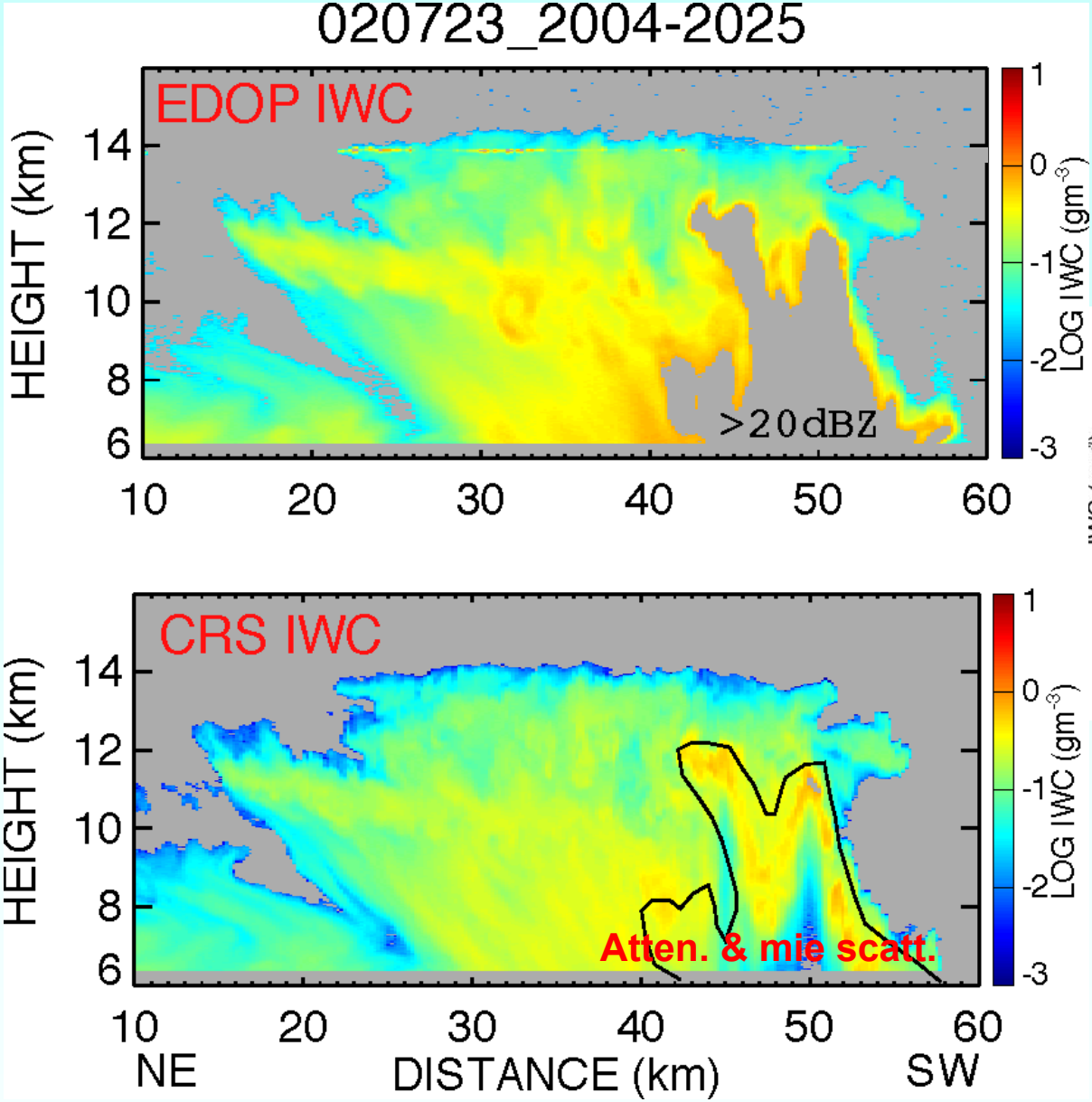
Decaying Towers and Cirrus Generation

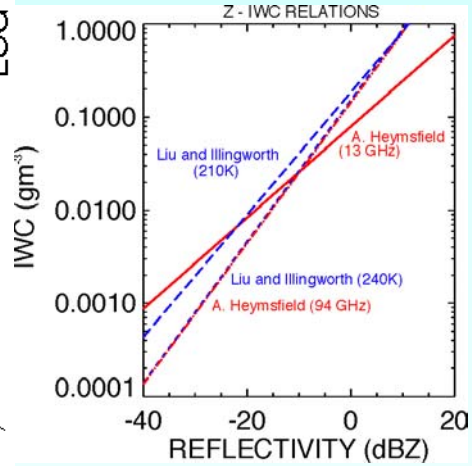


Complex Cirrus Layers Near Thunderstorms

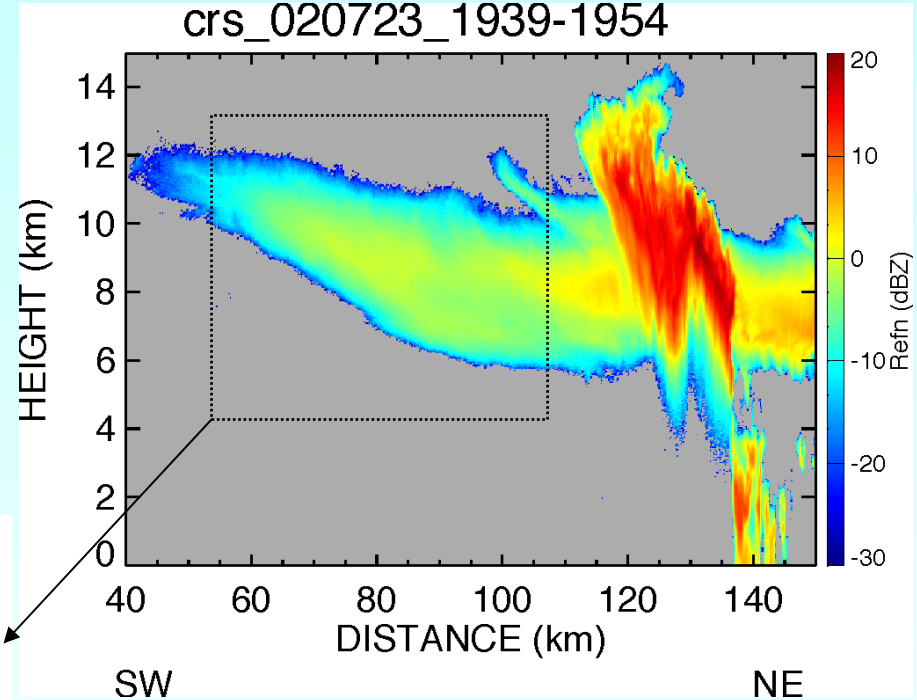


IWC Comparison-Single Frequency

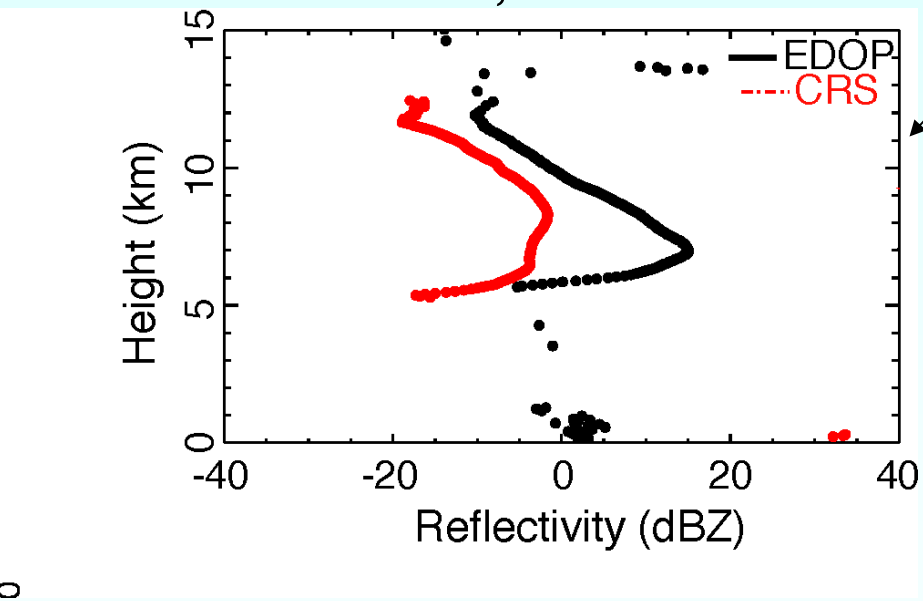




Particle Sizing in Cirrus Trail



Layer-averaged reflectivity
9.6 GHz, 94 GHz



Significant Mie scattering at 7-8 km altitude indicates location of largest particles.

Summary and Future Work

- Continue on 23 July case but also examine other cases with respect to shear effects on radar-observed convective structure and cirrus.
- Provide observational inputs for cirrus modeling studies (Starr, ..).
- Continue with CRS & EDOP calibration, data quality, data distribution.
- Work toward well-validated algorithms for IWC, fallspeeds, and particle sizes using EDOP, CRS, and CPL that can be applied to all C-F data for process studies. [*collaboration, CloudSat*].
- CRS upgrades for improved sensitivity.

Sounding and Winds
23 July 2003